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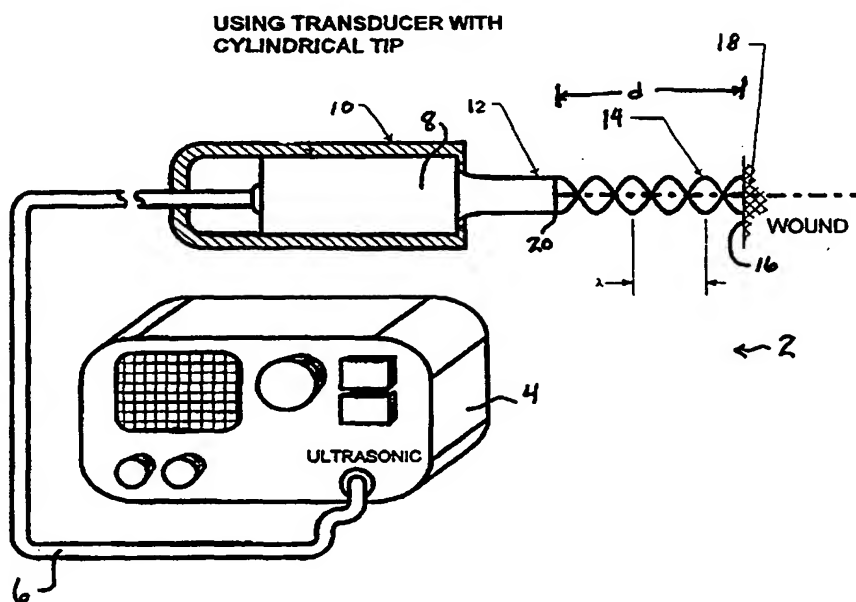
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(54) Title: **ULTRASOUND WOUND TREATMENT METHOD AND DEVICE USING STANDING WAVES**



(57) Abstract: The method and device of the present invention for wound treatment with ultrasound standing waves includes a transducer probe to produce ultrasonic waves. The ultrasonic transducer has a tip with a distal radiation surface that radiates ultrasound energy toward the surface of a wound. Ultrasound standing waves occurring as a result of incident and reflected waves from the wound surface create ultrasonic radiation pressure. ultrasound radiation pressure increases the blood flow in wound area, and ultrasound waves kill bacteria, stimulate healthy tissue cell and treat wounds.

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# ULTRASOUND WOUND TREATMENT METHOD AND DEVICE

## USING STANDING WAVES

### FIELD OF INVENTION

5 The present invention relates to the treatment of wounds using ultrasound standing waves. In particular, the present invention relates to a method and device of creating ultrasonic standing waves in air and directing them to a wound for delivering aerodynamic forces as ultrasonic radiation pressure and ultrasonic waves as well. Ultrasound radiation pressure increases the blood flow in the wound area, and ultrasound waves kill bacteria, stimulate healthy tissue cells, and treat the wound.

10

### BACKGROUND OF THE INVENTION

Ultrasonic waves have been widely used in medical applications, including diagnostics and therapy as well as many industrial applications, e.g., welding, cutting, fiber optics technology, speed meters, etc. Diagnostic use of ultrasound waves  
15 includes using ultrasonic waves to detect underlying structures in an object or human tissue. In this method, an ultrasonic transducer is placed in contact with the tissue or object via a coupling medium, and high frequency (1-10 MHz) ultrasonic waves are directed into the tissue. Upon contact with the various underlying structures, the waves are reflected back to a receiver adjacent the transducer. By comparison of the  
20 signals of the ultrasonic waves sent with the reflected ultrasonic wave as received, an image of the underlying structure can be produced. This technique is particularly useful for identifying boundaries between components of tissue and can be used to detect irregular masses, tumors, etc.

Three therapeutic medical uses of ultrasound waves include aerosol mist  
25 production, contact physiotherapy, and soft tissue ablation. The ultrasound contact physiotherapy procedure may cause a patient significant discomfort and/or pain, and skin may appear raw and damaged. Aerosol mist production makes use of a nebulizer

or inhaler to produce an aerosol mist for creating a humid environment and delivering drugs to the lungs.

5 Ultrasonic nebulizers operate by passing ultrasound waves of sufficient intensity through a liquid, the waves being directed at an air-liquid interface of the liquid from a point underneath or within the liquid. Liquid particles are ejected from the surface of the liquid into the surrounding air following the disintegration of capillary waves produced by the ultrasound. This technique can produce a very fine dense fog or mist.

10 Aerosol mists produced by ultrasound are preferred because a smaller particle size of the aerosol can be obtained with the ultrasonic waves. One of the major shortcomings of ultrasonic inhalers and nebulizers is that there is no directed aerosol to the target. An air stream is then required to direct the aerosol to the target, but this decreases the efficiency of ultrasound.

15 Ultrasonic sprayers (Sonic and Materials Inc., Misonix Inc., Sono-Tek Inc., Zevex International, Inc., operate by passing liquid through central orifice of ultrasound instrument-tip. See, for example, U.S. Patents Nos. 3,765,606; 4,659,014; 5,104,042; 4,930,700; 4,153,201; 4,655,393; 5,516,043; 5,835,678; 5,879,364; and 5,843,139.

20 Ultrasonic inhalers and drug delivery systems from Medisonic USA, Inc., 3M, Siemens Gmb, The Procter & Gamble Company, Sheffield Pharmaceuticals, Aradigm, Inc., operate by atomizing liquid using piezoceramic film. See, for example, U.S. Patents Nos. 4,294,407; 5,347,998; 5,520,166; 5,960,792; 6,095,141; 6,102,298; 6,098,620; 6,026,808; and 6,106,547.

## OBJECT OF THE INVENTION

It is an object of the invention to provide an improved method and device for treating wounds.

It is also an object of this invention to provide an improved method and device  
5 for treating wounds using ultrasound standing waves.

It is a further object of the invention to provide a method and device for increasing blood flow, killing bacteria, and stimulating healthy tissue cell growth.

These and other objects of the invention will become more apparent from the discussion below.

10

## SUMMARY OF INVENTION

The present invention is a method and device for using ultrasonic standing waves to treat wounds. Ultrasound standing waves occur as a result of incident and reflected waves from a reflective surface that are traveling in opposite directions. The  
15 resultant superposition of the two waves forms standing waves, which create ultrasonic radiation pressure. The standing waves, actually ultrasound radiation pressure, occur when the distance between (a) the distal end of a transducer (as a radiant of ultrasound waves) and (b) the reflected surface (e.g., a wound surface) is:  $n \times \lambda/2$ , where  $\lambda$  is the wave length and  $n$  is a positive integer. The standing waves are more effective in  
20 limited space or area as a tube.

According to the invention ultrasound waves are created, directed, and delivered to a wound surface through the air to increase blood flow, kill bacteria, stimulate healthy tissue cells and treat wounds with ultrasound energy. The method of treating wounds involves the use of ultrasound standing waves of a continuous or  
25 pulsed ultrasound.

More particularly, the method of the invention comprises producing ultrasound standing waves using a free end surface of an ultrasonic transducer and wound surface.

According to the method of the present invention, the radiation pressure of ultrasonic standing waves increase blood flow in wound area and destroy the surface bacteria to result in a higher disinfecting property of ultrasound. Additionally, the ultrasound also stimulates healthy cell growth to aid in granulization and epithelization of the healing tissue. Other applications of the method can be directed to non-medical uses such as cleansing, drying, sterilizing and coating surfaces of objects and food.

The method of the present invention offers an approach that may re-establish use of some traditional ultrasound and establish a method of treating wound and fighting bacteria without antibiotics when necessary.

The overall concept of the present invention relates in method and apparatus for wound treatment using ultrasonic standing waves through air with no drug. This wound treatment method is possible with combination of different energy sources as an ultrasound, laser, electric current, magnetic field, ultraviolet, microwaves, radio frequency, etc.

15

#### BRIEF DESCRIPTION OF DRAWINGS:

Fig. 1 is a perspective view of an ultrasound wound treatment system with standing waves, according to the present invention;

Fig. 2 is a schematic, lateral cross-sectional view of another transducer useful with the system of Fig. 1.

20

Fig. 3 is a schematic, lateral cross-sectional view of a transducer having a bushing;

Fig. 4 is a schematic, lateral cross-sectional view of a transducer of Fig. 3 where the distal tip has been modified to provide a focussed beam; and

Fig. 5 is a schematic, lateral cross-sectional view of an embodiment of the invention intended to facilitate dissolution of blood clots.

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## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is a method and system, which uses ultrasound standing wave energy to treat wounds. The system comprises a generator of electrical signals  
5 and a handpiece having an ultrasound transducer and tip.

The invention can perhaps be better appreciated from the drawings. A system for wound treatment according to present invention is illustrated in Fig. 1. The system 2 comprises a signal generator 4 operatively or electrically connected through cable 6 to a transducer 8 in a housing 10. Transducer 8 has an ultrasound tip 12 that generates  
10 standing ultrasound waves 14. Standing ultrasound waves 14 are directed to the surface 16 of a wound 18.

Standing ultrasound waves 14 occur when activated ultrasound tip 12 is directed through the air to a wound surface 16 as a result of incident and reflected waves from wound surface 16, which creates ultrasonic radiation pressure. The distal  
15 end 20 of transducer tip 12 (as a radiant of ultrasound waves) is preferably a distance  $d$  from wound surface 16 (a source of reflected waves). Distance  $d$  is related to the wavelength  $\lambda$  of the ultrasound wave or signal by the formula

$$d = n \times \lambda/2$$

where  $n$  is a positive integer. To reach this preferred distance and therefore effect  
20 wound treatment practice, ultrasound transducer 8 or tip 12 must frequently be moved back and forward toward wound surface 16 by an operator.

The waveform of the ultrasound waves generated by transducer 8 preferably corresponds to the waveform of the electrical signals generated by signal generator 4. For example, electrical signals from signal generator 4 with rectangular, sinusoidal,  
25 trapezoidal, or triangular waveforms will cause transducer 8 to produce respective similarly shaped ultrasound waveforms.

The standing waves are more effective in limited space or area such as a tube. In each of Figs. 3 to 5 a bushing 26 increases ultrasound radiation pressure. Bushing 26 may or may not be disposable part on the distal end 28 of housing 10.

In the embodiment of the invention set forth in Fig. 4 the distal end 28 of ultrasonic tip 12 has been modified to a concave shape to focus ultrasound waves 14.

One of the possible applications of the method of present invention is the facilitation of dissolution of blood clots by using ultrasound energy. In Fig. 5  
5 ultrasound tip 12 is directed to a blood vessel 30 with clot or clots 32. In this case ultrasound standing waves 34 create cavitation inside blood vessel 30 and dissolve clot or clots 32.

In another embodiment of the present invention a wound can also be treated with a gel or drug. After the gel or drug is applied to the wound surface, ultrasound  
10 standing waves would be directed to the wound. The drug would be activated and penetrate into tissue under ultrasound radiation pressure.

Additional possible application of method using ultrasound standing waves is for the diffusion of grafts to a wound with radiation pressure gently.

The preceding specific embodiments are illustrative of the practice of the  
15 invention. It is to be understood, however, that other expedients known to those skilled in the art or disclosed herein may be employed without departing from the spirit of the invention or the scope of the appended claims.



## I CLAIM:

1. A method of treating a wound, comprising the step of positioning an ultrasound transducer having a distal radiation surface to direct an ultrasound standing wave at a surface of a wound, wherein the distance d between distal radiation surface and the wound surface is determined by the formula

$$d = n \times \lambda / 2$$

wherein  $\lambda$  is the wavelength of the ultrasound standing wave and n is a positive integer.

2. The method of Claim 1, wherein the ultrasound transducer operates at a frequency of from about 10kHz to 10<sup>3</sup> MHz.

3. The method of Claim 1, wherein d is at least 0.1 in.

4. The method of Claim 1, wherein the ultrasound transducer is frequently moved back and forth in a longitudinal direction by an operator to reach a preferred distance to create a standing wave.

5. The method of Claim 1, wherein the ultrasound standing wave creates radiation and/or pressure that energizes the wound.

6. The method of Claim 1, wherein in a prior step a gel, drug, or other medicant is applied to the wound surface.

7. The method of Claim 6, wherein any medical effect of the gel, drug, or other medicant is energized by the ultrasound standing wave.

8. The method of Claim 1, wherein the ultrasound standing wave has an ultrasound radiation, pressure, massage, and/or sterilization effect.

9. A system for treating a wound with ultrasound standing waves, comprising

a generator for generating ultrasound waves,

an ultrasound transducer operatively connected to said generator and having a distal radiation surface, and

FIGURE 3

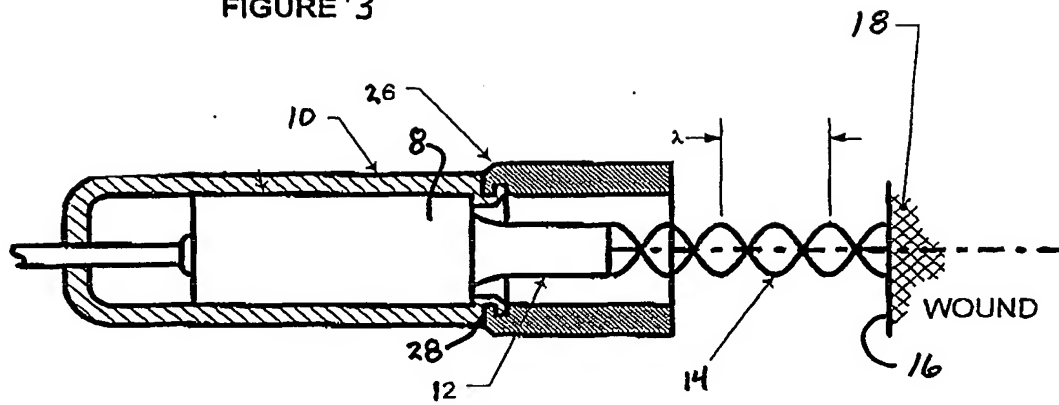


FIGURE 4

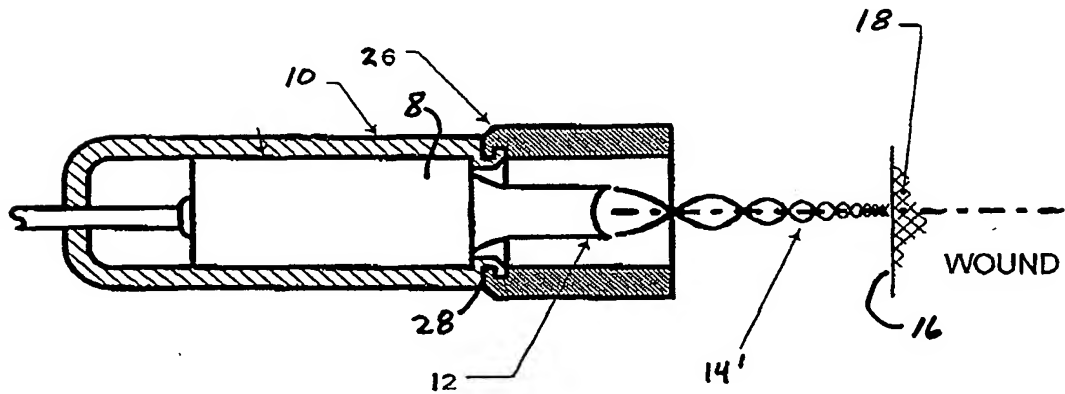
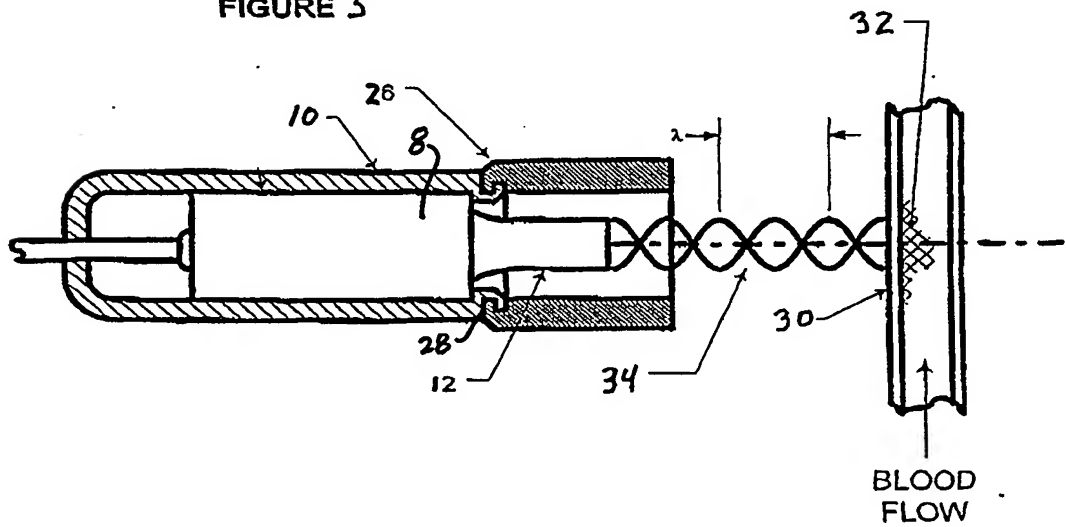


FIGURE 5



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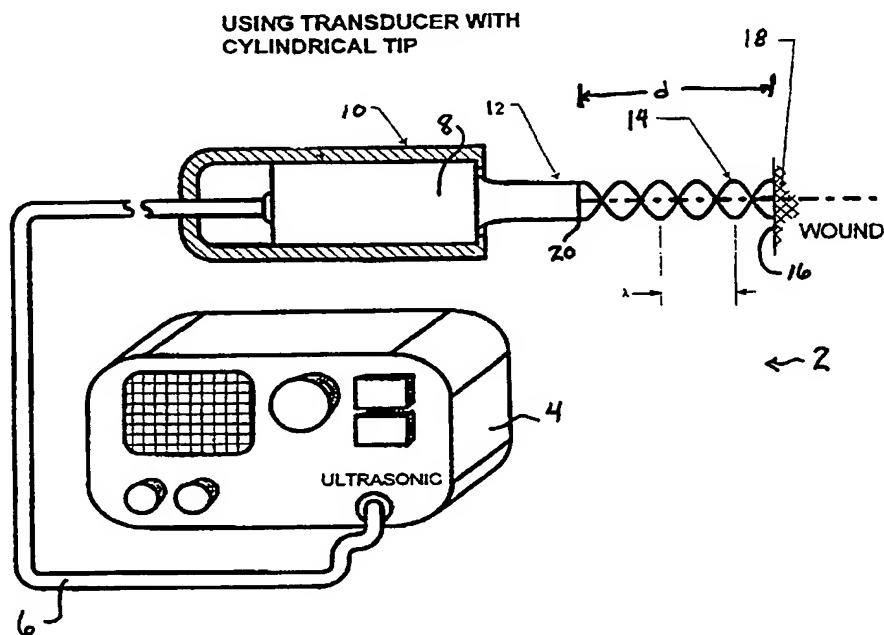
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- (72) Inventor; and (75) Inventor/Applicant (*for US only*): **BABAEV, Eilaz** [US/US]; 5564 Bimini Drive, Minnetonka, MN 55343 (US).
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# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US02/02724

## A. CLASSIFICATION OF SUBJECT MATTER

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According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 601/2; 604/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 6,007,499 A (MARTIN et al.) 28 December 1999, see figures 6-8 and col. 13 line 59 - col. 15 line 54.	1-5, 9, 10, 12-14, 18 ----- 6-8, 15-17
Y	US 5,895,362 A (ELSTROM et al.) 20 April 1999, see col. 2 lines 8-56 and col. 4 lines 33-38.	6-8, 15-17

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	
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